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EFFECTS OF COBALT-60 IRRADIATION TO THE
REGION OF THE BRAIN OF THE BURRO
HEMATOLOGICAL RESPONSES FOLLOWING EXPOSURES
OF 200 r AND 600 r

by

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New Mexico

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FOREWORD

This is the second in a series of reports describing the effects of cobalt-60 irradiation to the brain of the burro. The first, AFSWC TDR-62-96, was published in January 1963, and presented clinical signs and symptoms.

Captain Engel holds degrees of Ph.D. and D.V.M., and is presently serving with the Radiation Effects Laboratory, Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico. Miss Cartwright is research technician, College of Veterinary Medicine, University of Minnesota, St Paul 1, Minnesota. Dr. Spurrell is Associate Professor, Division of Surgery and Radiology, College of Veterinary Medicine, University of Minnesota, St Paul 1, Minnesota.

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ABSTRACT


Twenty-two adult male burros were exposed to cobalt-60 radiation to the head only. Six out of seven receiving 600 r died. In contrast, six out of six burros receiving 200 r survived.

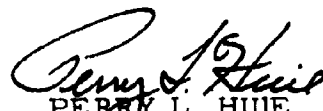
Acute hematological changes observed in the 600 r irradiated group were in close agreement with early acute blood changes observed in whole-body irradiation of burros and other mammalian species. Early hematological responses were valuable prognostic aids for determining degree of brain and/or pituitary injury.

PUBLICATION REVIEW

This report has been reviewed and is approved.


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AIR FORCE WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base
New Mexico

16 December 1963

ERRATUM

RTD TDR-63-3027. EFFECTS OF COBALT-60 IRRADIATION TO THE
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EXPOSURES OF 200 r AND 600 r

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1. INTRODUCTION.

Tissue of the central nervous system appears to be relatively resistant to injury by lower doses of ionizing radiation, although symptoms of neurological deficit occur in all mammalian species following large radiation doses. Neurological examinations, peripheral blood and bone marrow studies are frequently used to evaluate degrees of radiosensitivity.

Kuhn and Brown¹ exposed the brain of the anesthetized burro to cobalt-60 radiation. Neurological abnormalities were noted in animals exposed from 150 to 2216 rad. A hematological response was characterized by a leukocytosis within 24 hours post-exposure. The leukocytosis was chiefly due to an increase in mature neutrophils; however, immature neutrophils also increased in number between 12 and 24 hours post-exposure. The lymphocytes and eosinophils followed erratic patterns, but were generally depressed in the groups that received the highest doses.

It is evident that central nervous-system changes accompanied by hematological alterations occur at relatively low doses of ionizing radiations in the burro when compared to other mammals. For this reason studies on the response of an unanesthetized burro to low doses of gamma radiation to the brain were indicated.

2. MATERIAL AND METHODS.

Twenty-two normal adult male burros were paired, as closely as possible, according to color, weight, height, disposition, and age. Seven pairs were assigned to the group to be irradiated with 600 r and four pairs to the 200 r group. One animal of each pair served as a control. Each animal was bled according to a set time schedule (table 1).

Blood for the studies herein reported was obtained from the jugular vein. Five cubic centimeters were withdrawn into a tube containing 2,000 units of heparin sodium solution. Blood smears were immediately prepared and stained with modified Wrights' stain.² A Model-A Coulter electronic blood-

cell counter was used to meter the red and white blood cells.^{3,4} The hemoglobin was measured by the cyanmethemoglobin method using a Coleman Jr. Spectrophotometer. The packed cell volume (PCV) was determined by the microhematocrit procedure.⁵ Differential cell counts were recorded according to the various cell types found in the burro (tables 3 to 6).²

Composite graphs were made for all blood values. The absolute blood values of each animal were used in calculation for composite presentations. The mean values of each group were used for graphing. The 95 percent confidence interval for the sample standard deviation and the sample standard deviation of the mean, for the period of -6 days to -2 hour values, were computed as described by Snedecor⁶ (table 2).

Irradiation was accomplished using cobalt-60 sources arranged to simultaneously irradiate the brain from both sides, i.e., bilaterally.⁷

3. RESULTS.

a. 600 r Group.

The hemoglobin, hematocrit, and RBC values indicate that a moderate degree of hemoconcentration occurred in both the principals and controls (figure 1). Maximum response was the period immediately following sham and actual irradiation. Return to pre-exposure levels was noted 1.5 hours following the peak response.

The medium and small lymphocytes for all pairs increased and then decreased (figures 2, 3). At +3.5 hours the lymphocytes of the control burros returned to pre-exposure levels while those of the irradiated ones continued to decrease until +16.5 hours. At +3 days, the values of irradiated burros were still slightly below normal, but appeared to be increasing rapidly. The number of large lymphocytes remained constant in the irradiated and control animals.

Transitional lymphocytes and monocytes increased slightly in the post-irradiation period. The plasma cellular lymphocytes and plasma-cell precursors dropped to approximately 50 percent of normal from the time

of irradiation until + 32.5 hours after which they gradually increased until the sixth week post-exposure (figures 2, 3).

Irradiation-induced leukocyte changes were noted (figures 4, 5). An initial leukocytosis occurred within + 1.5 hours and a delayed leukocytosis occurred within + 9.5 hours post irradiation. The delayed neutrophilia occurring at + 9.5 hours was observed until + 24.5 hours. Segmented neutrophils decreased by + 40.5 hours; however, a neutrophilia still persisted. The immature and stab neutrophils began to increase at + 5.5 hours and reached a 15-fold increase by + 10.5 hours. A gradual decline to pre-irradiation levels occurred by + 32.5 hours.

Eosinophil values of the irradiated burros began to decrease by + 4.5 hours, reached virtually zero by + 12.5 hours, and remained there until death had occurred (figures 4, 5). Six out of seven burros died in the terminal phase of a hyperacute radiation syndrome.⁷

b. 200 r Group.

The hemoglobin, hematocrit, and red blood cell values were much the same as in the 600 r group, indicating an initial hemoconcentration. Irradiated and control burros exhibited similar hematological patterns from -6 through +6 weeks (figures 6-9). A few transient, abnormal neurological signs were noted, but no deaths occurred in this group.⁷

4. DISCUSSION.

Considerable experimental evidence supports the concept that, in the blood stream, leukocytes flow in the marginal regions and adhere to capillary walls, and that epinephrine and physical exertion will decrease the plasma volume and increase the size of the circulating granulocyte pool, although not increase the size of the total granulocytic pool.⁸ This would explain the hemoconcentration and rise in leukocyte numbers during the early phases of sham-irradiation and irradiation and their return to normal levels after removal of the burros from the stress-invoking environment.

A leukocytosis consisting of two peaks, one at 8 to 12 hours and one at 24 hours post-exposure, were observed in a number of species exposed to whole-body irradiation.⁹ Early lymphopenia and neutrophilia were noted in the rat during the first 24 hours following large whole-body doses of X ray.^{10, 11} Eldred and Eldred¹² reported leukocytosis due entirely to a rise in neutrophils 1 to 5 hours post-irradiation in the monkey. The rabbit exhibited an initial rise in absolute heterophil (proper name for granulocytes of the rabbit) values at 12 to 24 hours after 500 r and 800 r whole-body doses of X radiation.¹³ Man and swine exhibited a neutrophilia within a few hours after whole-body irradiation.¹⁴⁻¹⁸ Chimpanzees showed a marked neutrophilia and a profound decrease in lymphocytes and monocytes within 30 hours post-irradiation.¹⁹ The dog exhibited granulocytosis following exposures of 10 to 25 r of X ray.²⁰ A leukocytosis was reported in the burro within 24 hours after whole-body irradiation.^{1, 21}

The appearance of a delayed leukocytosis, which was observed only in burros exhibiting gross neurological abnormalities, may have been due to a leukocytosis-promoting factor in the plasma that mobilized granulocytes from the bone marrow.^{22, 23} The increased numbers of immature forms thrown into the peripheral circulation offer more evidence in favor of an outpouring of the granulocyte marrow reserves.²⁴⁻²⁶

Dougherty described five phases in the lymphocytic response to stress.²⁷ In Phase 1, there was an immediate increase in lymphocytes following non-irradiation stress. This rise was attributed to epinephrine secretion and physical exertion. Phase 2 was the development of lymphopenia which is mediated by the adrenal-cortical secretions in intact animals. Phase 3 was the period of reconstitution of the lymphocytes from the lowest lymphocytic level to the normal limits. Phase 4 (overshooting normal limit) and Phase 5 (return to normal limit) were not observed in the burro irradiated to the brain.

The long-recognized lymphocytolytic effect of small exposures of radiation is dependent on pituitary-adrenal-cortical mediation, while in large doses the direct action is on the lymphoid tissue.²⁹

Dougherty and White,²⁸ working with adrenalectomized mice, state,

It is suggested that X rays exert both a direct and indirect effect on lymphocytes. The direct action may be manifested even in the absence of the pituitary or adrenals, whereas the indirect action of X irradiation on lymphocytes is mediated via the pituitary-adrenal-cortical mechanism.

In all probability only the circulating lymphocytes were exposed to gamma radiation; therefore, the major factor leading to the lymphopenia observed in Phase 2 must have been the effects of the pituitary-adrenal mechanism.

Further evidence that the lymphopenia may be mediated by the influence of the pituitary-adrenal axis was found in the response of the circulating eosinophils. The eosinophil count serves as a measure of reaction of the pituitary-adrenal-cortical system to stress.³⁰⁻³⁴ Injection of adrenal-cortical hormones or ACTH into an animal will produce a peripheral eosinopenia.^{26, 35-37} Eldred³⁸ reported a 49 percent eosinophil decrease in the first to third days in the monkey irradiated with 600 r of X rays to the whole body. On the fourth and fifth days, eosinophils were seriously depleted and thereafter were scarce up to the fourth week at which time the cell rapidly reappeared. Kuhn and Brown¹ noted that in the burro irradiated to the head the peripheral blood pattern of eosinophils was similar to that of lymphocytes.

If the reader accepts the pituitary-adrenal-axis as one of the factors governing numbers of circulating eosinophils and lymphocytes, then the results of this study indicate that brain and/or pituitary damage caused by gamma radiation and eosinopenia and lymphopenia are correlated. It is suggested that the degree of eosinopenia neutrophilia and lymphopenia can be used to judge the severity of neurological deficits in the burro after exposure of the head with cobalt-60 gamma rays.

5. SUMMARY.

Twenty-two burros were paired for neurological and hematological studies. Blood collections were made during four periods: (a) daily from 6 to 3 days before irradiation; (b) pre-sham irradiation; (c) sham-irradiation; and (d) post-irradiation.

Seven burros received 600 r and four burros 200 r of gamma rays to the brain from bilateral-positioned cobalt-60 sources. Each had a paired control that was sham-irradiated. Six out of seven burros receiving 600 r died in the terminal phase of a hyperacute radiation syndrome. The animals that received 200 r showed few transient abnormal neurological signs.

The acute hematological changes observed in the 600 r irradiated group were in close agreement with early acute blood changes observed in whole-body irradiation of burros and other mammalian species. Early hematological responses, particularly eosinophilia and neutrophilia, were valuable prognostic aids for determining the degree of brain and/or pituitary injury.

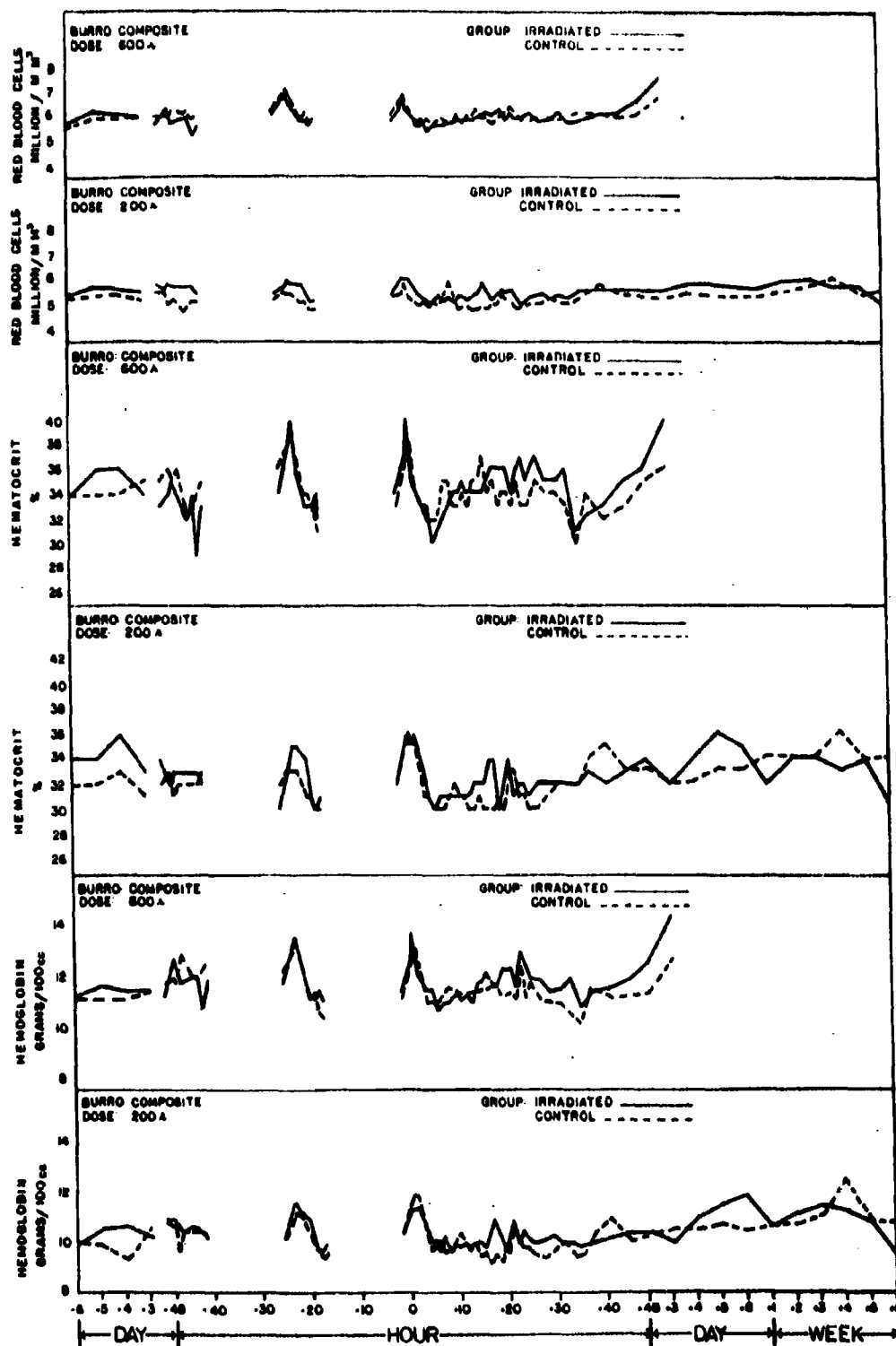


Figure 1. Composite Graph Showing Red Blood Cells, Hematocrit, and Hemoglobin Values of the Irradiated and Control Groups

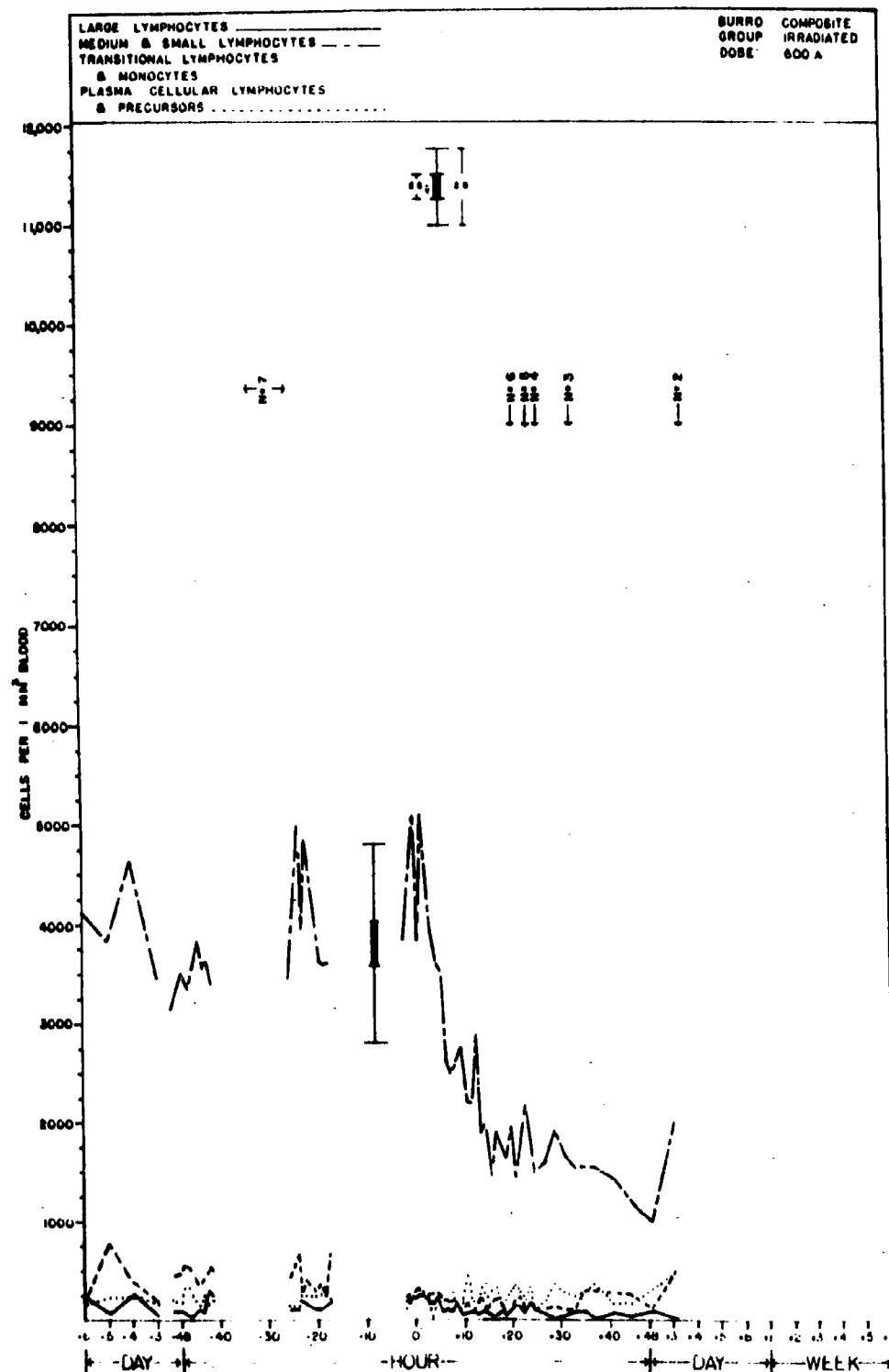


Figure 2. Composite Graph of Lymphocytes of the 600 r Irradiated Group

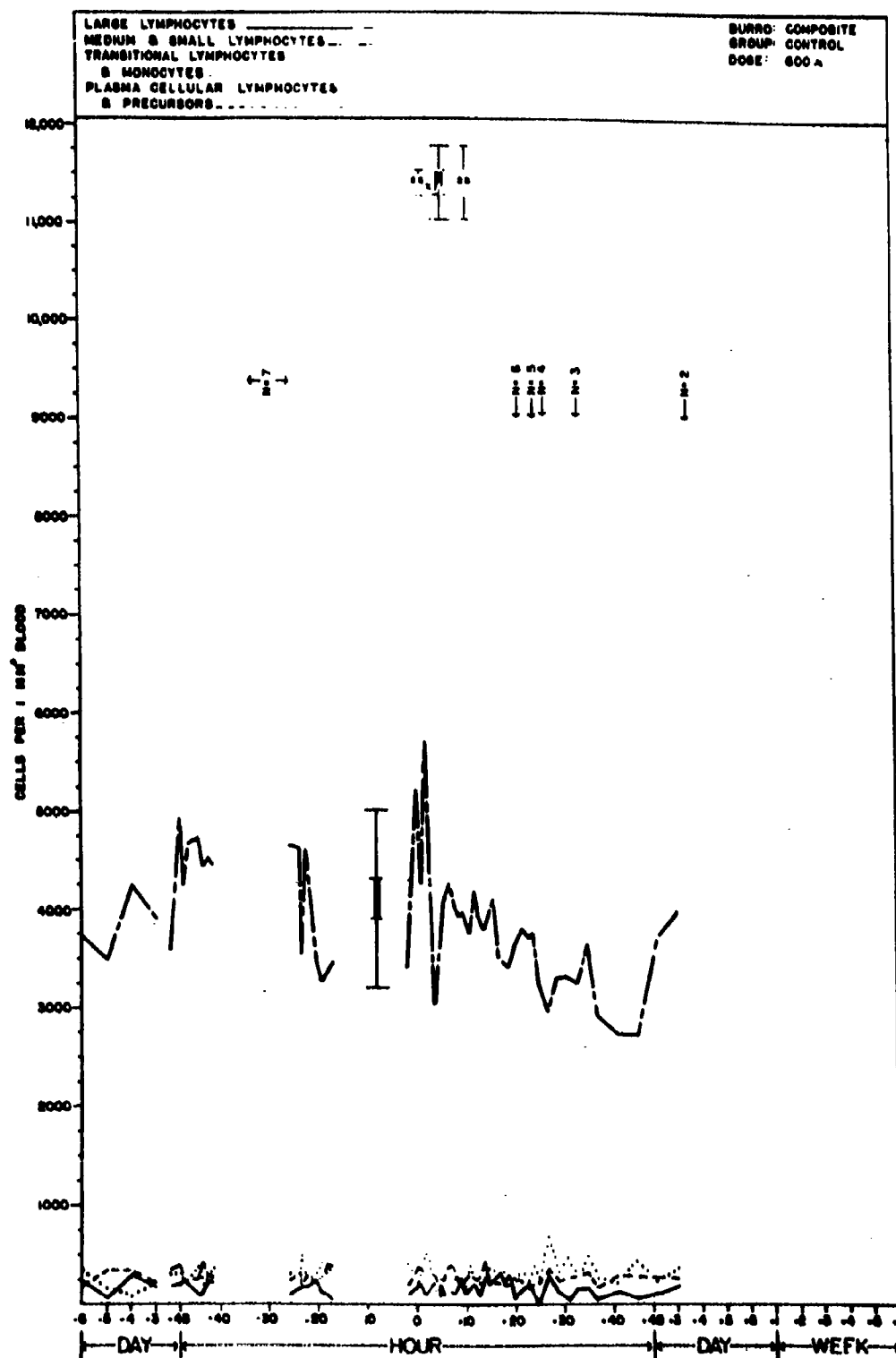


Figure 3. Composite Graph of Lymphocytes of the 600 r Control Group

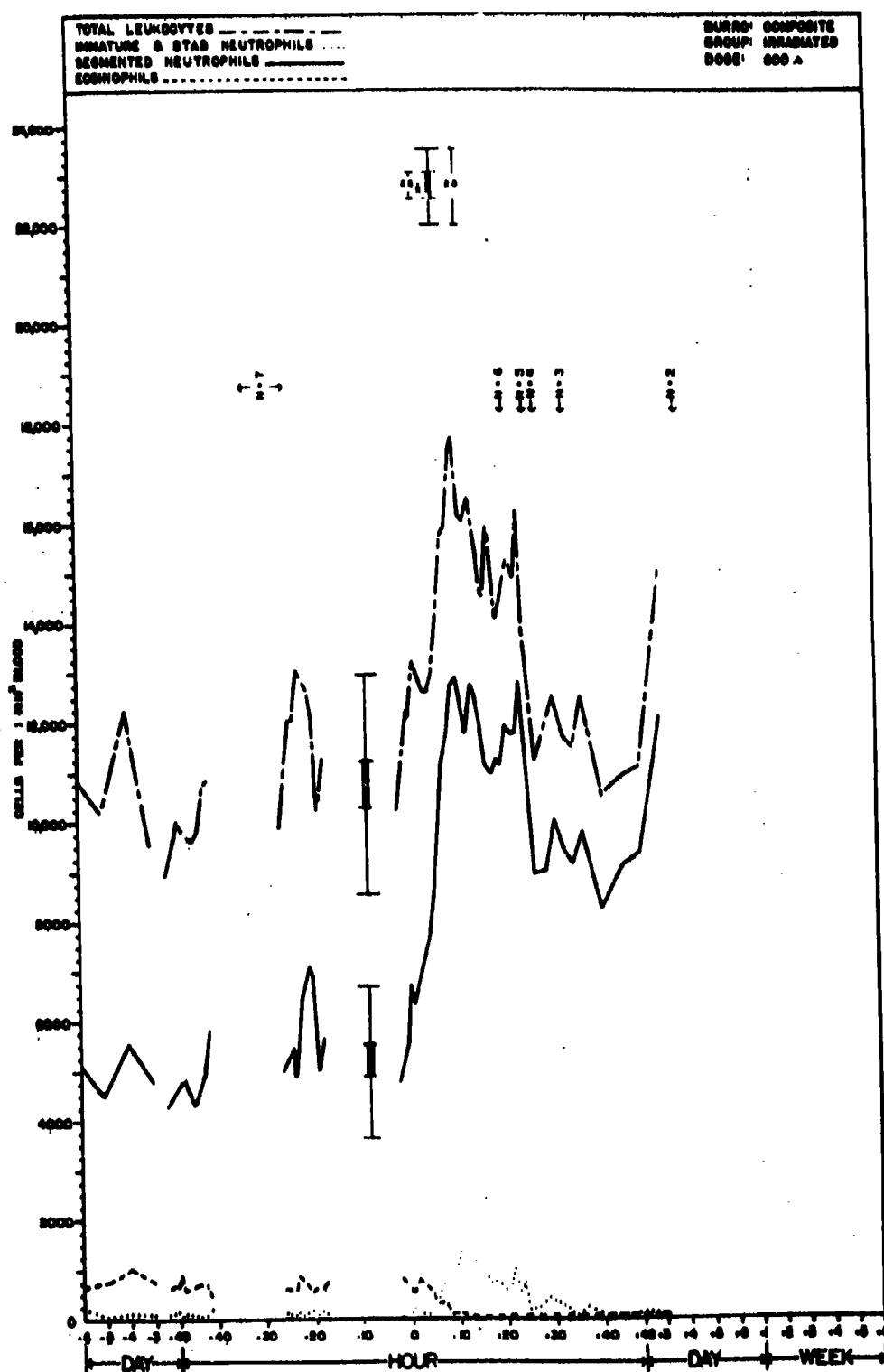


Figure 4. Composite Graph of Segmented Leukocytes of the 600 r Irradiated Group

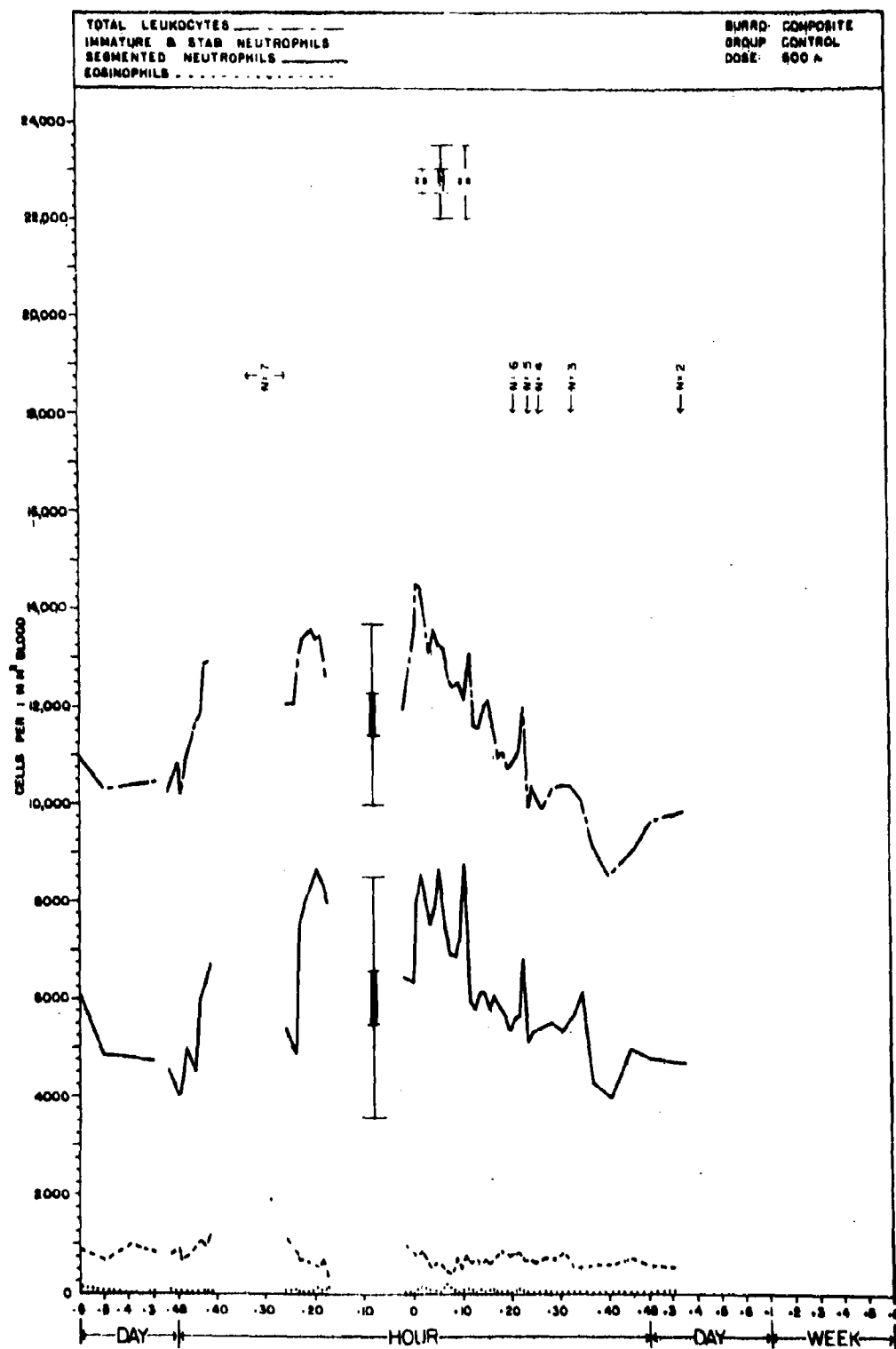


Figure 5. Composite Graph of Segmented Leukocytes of the 600 r Control Group

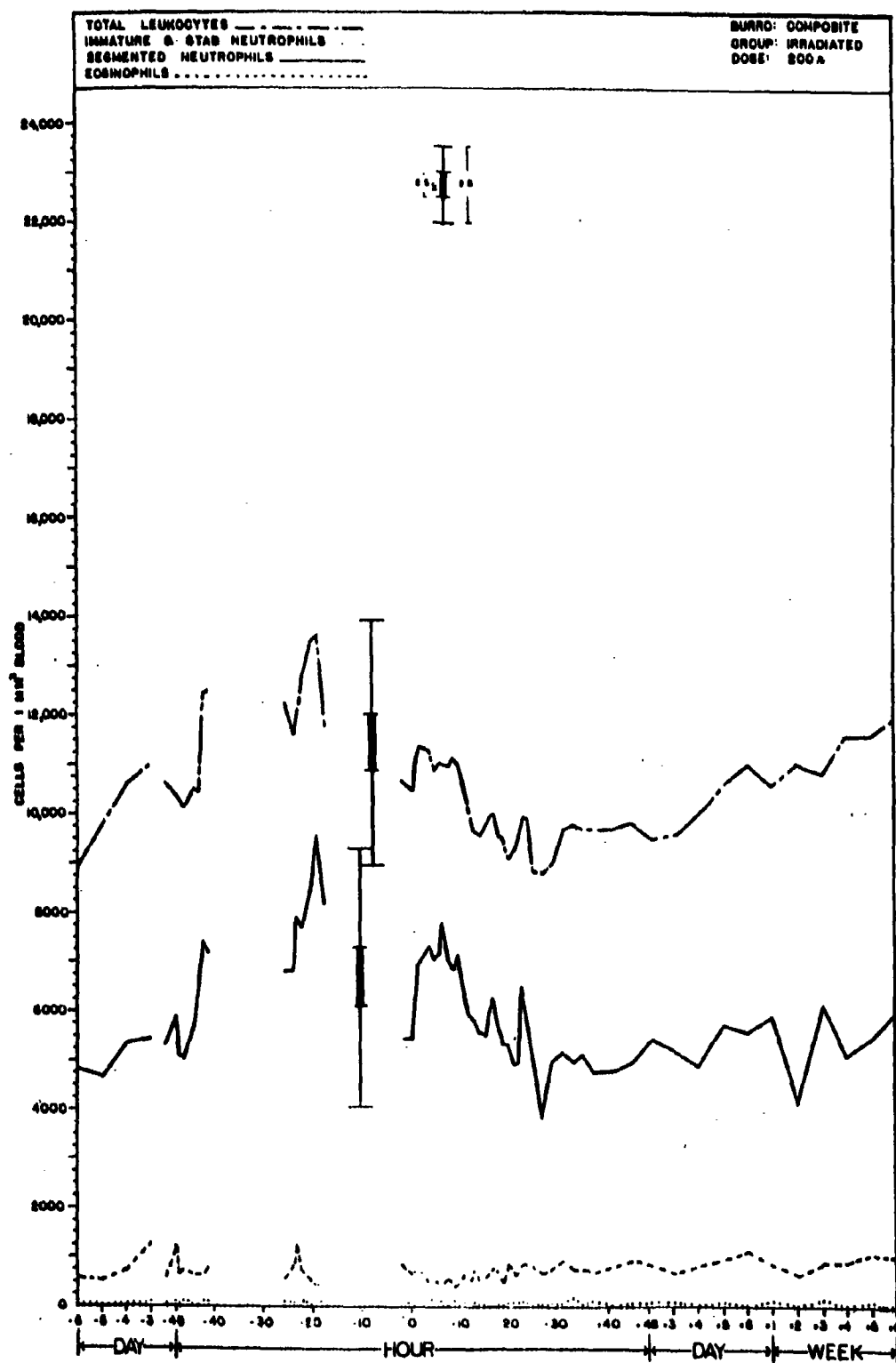


Figure 6. Composite Graph of Segmented Leukocytes of the 200 r Irradiated Group

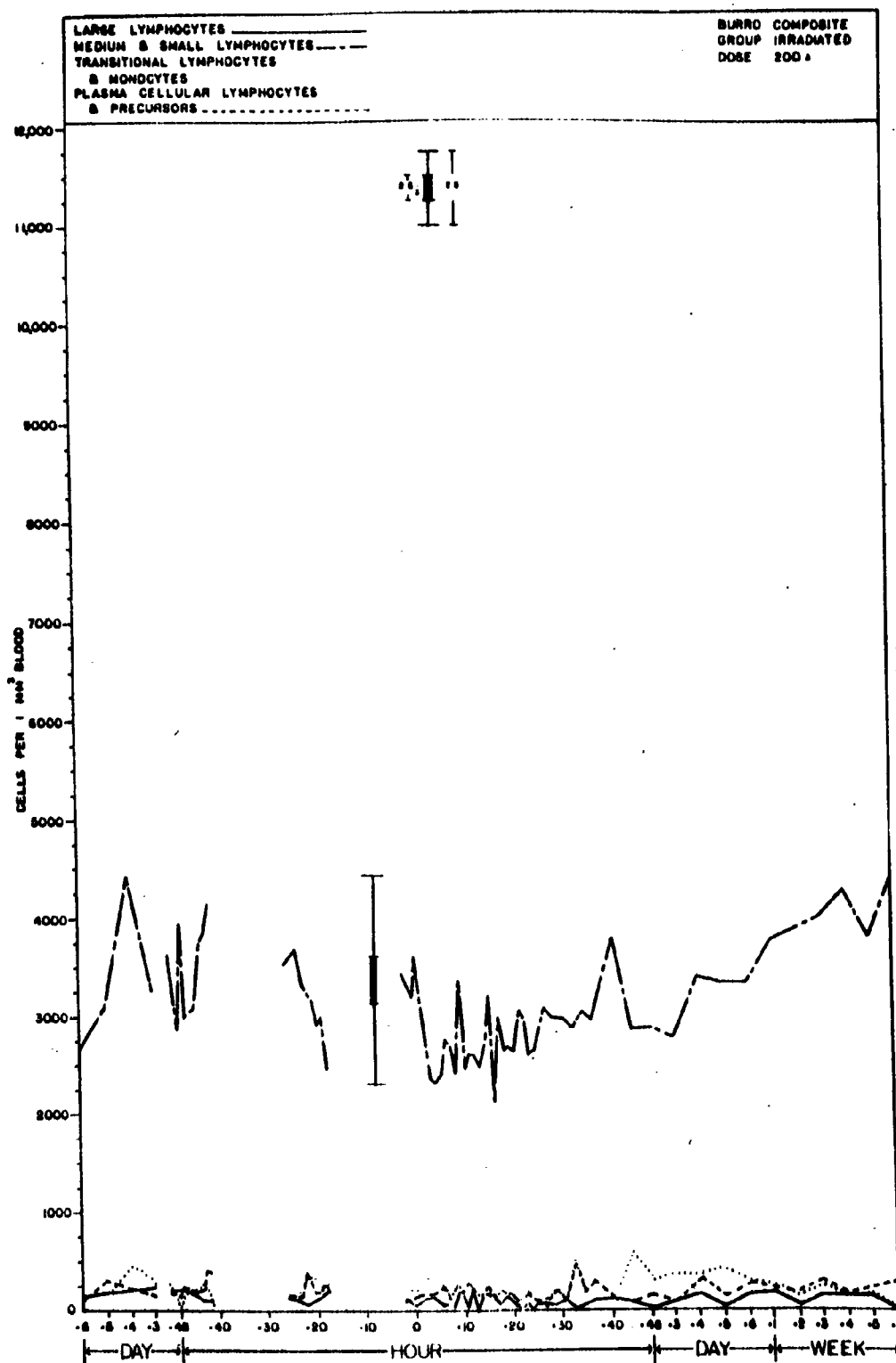


Figure 7. Composite Graph of Lymphocytes of the 200 r Irradiated Group

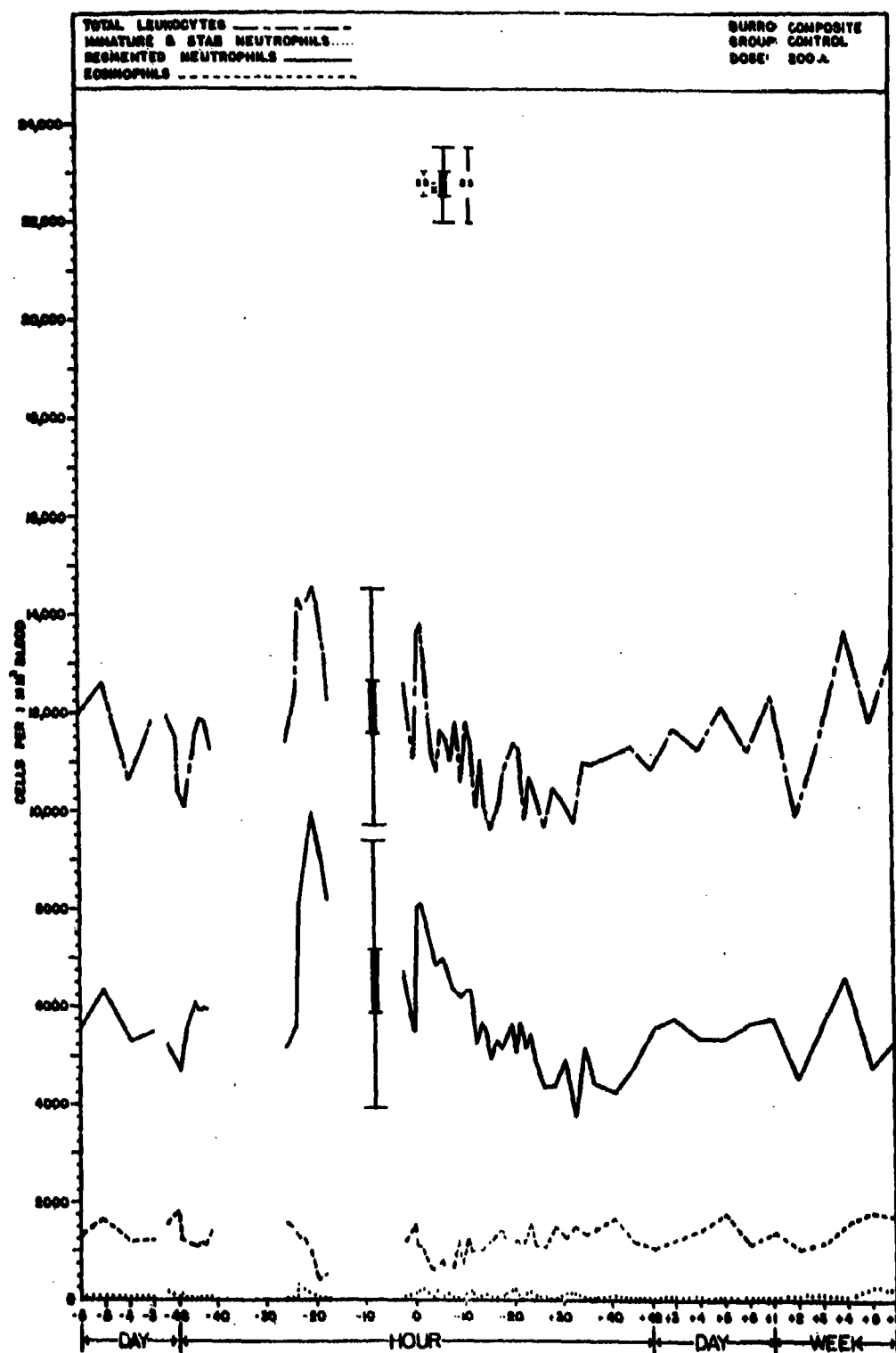


Figure 8. Composite Graph of Segmented Leukocytes of the 200 r Control Group

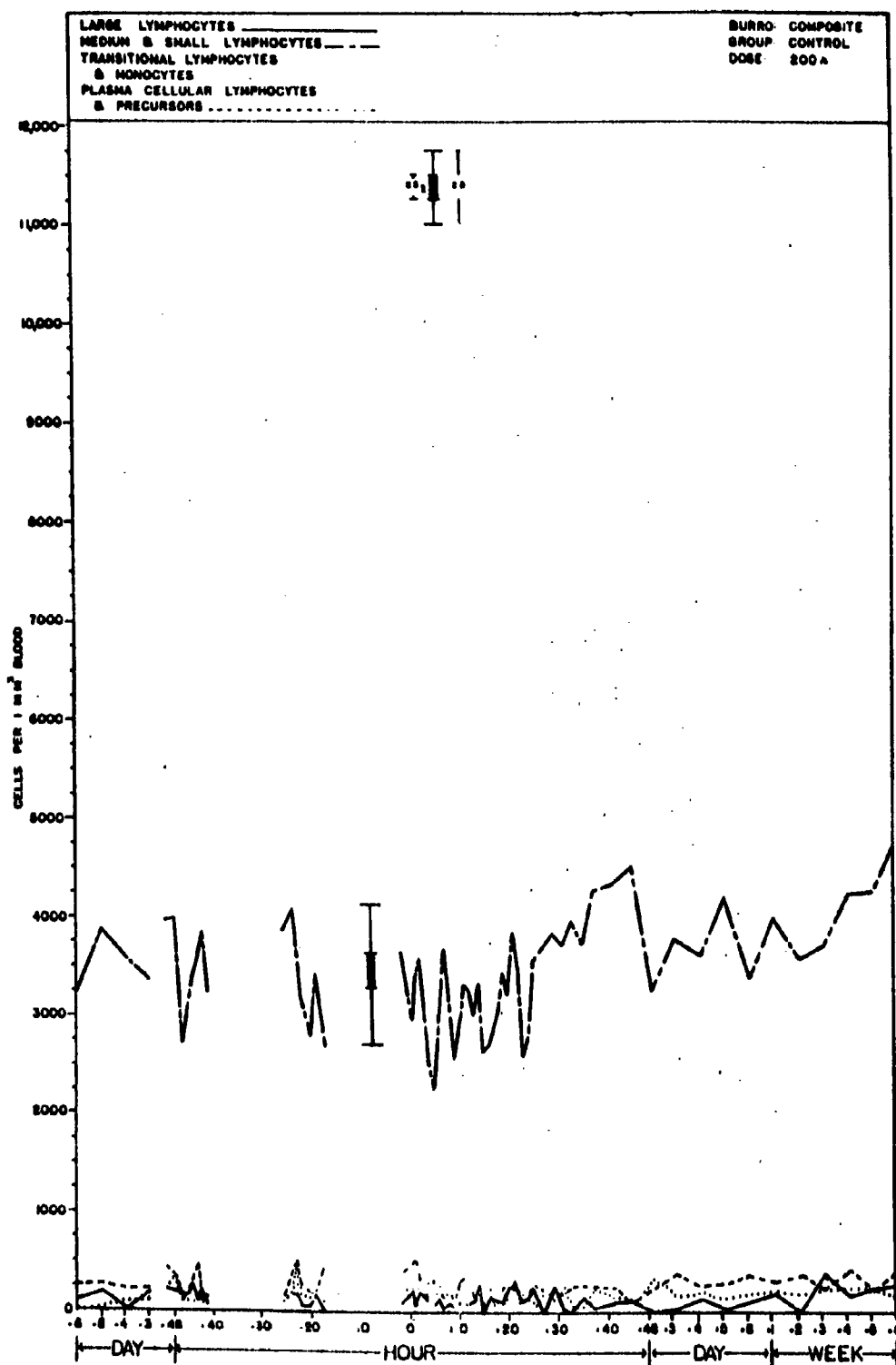


Figure 9. Composite Graph of Lymphocytes of the 200 r Control Group

Table 1. BLEEDING SCHEDULE

Identification of blood samples	Event
-6 day to -3 day	Daily -- pre-exposure
<u>Pre-sham irradiation</u> (diurnal variation)	
-50 hour	Corresponds to pre-irradiation (-2 hr)
-48 hour	Corresponds to arrival at irradiation site (0 hr)
-47.5 hour to -41.5 hour	Corresponds to post-irradiation
<u>Sham irradiation</u>	
-26 hour	Pre-sham exposure
-24 hour	Arrival at irradiation site
-23 hour	Corresponds to immediately following exposure (0 hr)
-22.5 hour	Return from irradiation site
-21.5 hour to -17.5 hour	Post-sham exposure
<u>Irradiation</u>	
-2 hour	Pre-irradiation
0 hour	Arrival at irradiation site
+ .5 hour	Immediately following irradiation
+1.5 hour	Return from irradiation site
+2.5 hour to +24.5 hour	Hourly post-exposure
+26.5 hour to +36.5 hour	Two-hour intervals -- post-exposure
+36.5 hour to +48 hour	Four-hour intervals -- post-exposure
+3 days to +7 days	Daily post-exposure
+2 weeks to +6 weeks	Weekly post-exposure

Table 2. MEAN, \bar{X} , SAMPLE STANDARD DEVIATIONS AND SAMPLE STANDARD DEVIATION OF THE MEAN $S\bar{X}$ FOR PRE-IRRADIATION HEMATOLOGICAL VALUES, N = 20

Group	HB gm/100cc	HEM %	RBC $\times 10^6$	WBC	EOS	IMM STAB	SEG	TRANS	LL	M&S	PCP PCL
Irradiated \bar{X}	11.7	34	5.96	10,745	662	72	5,197	216	131	3,798	433
600 r 2 s	1.54	5.9	0.90	2,198	294	104	1,522	104	150	998	316
2 s \bar{X}	0.34	1.3	0.20	492	64	46	340	24	34	222	70
Control \bar{X}	11.6	34	6.06	11,828	803	46	6,011	280	150	4,096	275
600 r 2 s	1.44	4.2	0.60	1,850	428	68	2,468	210	100	902	136
2 s \bar{X}	0.32	0.8	0.12	412	90	30	552	46	22	200	60
Irradiated \bar{X}	10.4	31	5.57	11,419	708	51	6,606	225	153	3,366	232
200 r 2 s	1.10	2.7	0.48	2,506	490	50	2,626	222	84	1,056	162
2 s \bar{X}	0.24	0.58	0.11	560	108	10	286	48	20	236	36
Control \bar{X}	10.1	29	5.16	12,116	1,174	54	6,526	166	149	3,464	292
200 r 2 s	1.00	1.6	0.44	2,426	770	156	2,864	282	138	750	194
2 s \bar{X}	0.22	0.4	0.10	542	172	34	640	62	30	168	42
HB - Hemoglobin	EOS - Eosinophils										
HEM - Hematocrit	IMM - Immature neutrophils										
RBC - Red blood cells	STAB - Stab neutrophils										
WBC - White blood cells	SEG - Segmented neutrophils										
	TRANS - Transitional lymphocytes										
	LL - Large lymphocytes										
	M&S - Medium & small lymphocytes										
	PCP - Plasma cell precursors										
	PCL - Plasma cellular lymphocyte										

Table 3. ABSOLUTE HEMATOLOGICAL VALUES

Burro: Composite		Group: Irradiated		Dose: 600 r								
R HOUR	HB	HEM	RBC	WBC	EOS	IMM STAB	SEG	TRANS	LL	M & S	PCP PCL	
<u>Pre-sham irradiation</u>												
-6 day	11.1	34	5.69	10,800	605	195	5,118	153	232	4,130	239	
-5 day	11.5	36	6.16	10,200	711	0	4,455	220	59	3,810	760	
-4 day	11.3	36	6.12	12,200	979	72	5,544	235	245	4,641	390	
-3 day	11.4	34	5.98	9,500	731	61	4,738	165	30	3,459	170	
-50 hr	11.1	33	5.86	8,900	615	55	4,259	218	78	3,126	438	
-48 hr	12.6	34	6.23	9,700	634	102	4,586	186	82	3,492	462	
-47.5 hr	12.6	35	6.34	10,000	858	0	4,699	330	60	3,440	550	
-46.5 hr	11.6	34	5.75	9,800	542	78	4,770	325	29	3,366	539	
-44.5 hr	11.8	32	5.77	9,600	666	41	4,250	148	116	3,837	350	
-43.5 hr	12.0	34	5.88	9,800	634	0	4,580	250	72	3,535	439	
-42.5 hr	10.6	29	5.18	10,600	692	49	4,964	148	313	3,626	536	
-41.5 hr	11.8	33	5.55	10,800	428	168	5,792	195	216	3,383	485	
<u>Sham irradiation</u>												
-26 hr	11.6	34	6.00	9,900	593	86	4,981	146	101	3,486	414	
-24 hr	13.2	38	6.59	12,000	565	66	5,427	134	109	4,990	678	
-23.5 hr	13.5	40	6.85	12,000	835	87	4,878	289	192	3,908	272	
-22.5 hr	12.5	36	6.41	13,000	743	61	6,304	232	157	4,859	408	
-20.5 hr	11.1	33	5.77	12,600	518	115	7,089	243	99	4,094	284	
-19.5 hr	11.0	33	5.78	12,100	599	76	6,877	255	108	3,625	370	
-18.5 hr	11.3	34	5.58	10,200	586	97	4,976	259	149	3,580	245	
-17.5 hr	10.9	32	5.84	11,200	715	49	5,658	196	173	3,596	645	
<u>Irradiation</u>												
-2 hr	11.2	34	5.74	10,200	802	12	4,760	104	169	3,839	235	
0 hr	12.5	37	6.15	12,200	575	71	5,527	292	218	5,085	243	

Table 3 (cont'd)

R HOUR	HB	HEM	RBC	WBC	EOS	IMM STAB	SEG	TRANS	LL	M&S	PCP PCL
+ .5 hr	13.4	40	6.68	12,100	473	179	6,703	218	261	3,820	307
+ 1.5 hr	11.9	35	6.12	13,200	774	102	6,360	265	232	5,100	225
+ 3.5 hr	11.3	33	5.72	12,600	603	60	7,250	174	149	3,974	260
+ 4.5 hr	11.3	33	5.79	12,600	504	163	7,443	203	243	3,629	271
+ 5.5 hr	10.5	30	5.26	13,100	286	408	8,365	34	59	3,514	197
+ 6.5 hr	10.8	31	5.49	14,200	319	672	9,753	202	107	2,655	182
+ 7.5 hr	10.8	32	5.52	15,600	222	905	11,197	274	75	2,491	172
+ 8.5 hr	11.0	33	5.54	15,900	83	870	11,713	156	161	2,574	176
+ 9.5 hr	11.2	34	5.62	17,000	72	1,081	12,728	165	38	2,747	78
+ 10.5 hr	10.9	34	5.60	17,700	74	1,469	12,905	464	242	2,202	185
+ 11.5 hr	11.1	35	5.74	10,200	29	1,140	12,267	217	83	2,195	44
+ 12.5 hr	11.2	34	5.74	16,000	0	1,176	11,810	135	42	2,869	203
+ 13.5 hr	11.2	34	5.74	16,500	32	1,119	12,809	320	87	1,877	210
+ 14.5 hr	11.3	34	5.70	15,900	0	847	12,533	244	63	2,000	90
+ 15.5 hr	11.3	34	5.83	14,800	21	966	11,933	291	20	1,440	183
+ 16.5 hr	11.5	35	5.88	14,500	21	714	11,189	325	44	1,898	202
+ 17.5 hr	11.5	36	5.96	15,900	0	741	10,977	169	94	1,702	162
+ 18.5 hr	12.1	36	5.92	14,100	51	684	11,248	196	33	1,643	78
+ 19.5 hr	12.1	36	6.14	14,100	0	594	11,125	281	75	1,842	408
+ 20.5 hr	12.2	36	6.17	14,800	19	522	11,922	359	143	1,437	227
+ 21.5 hr	11.4	34	5.74	15,200	23	1,000	11,788	280	120	1,701	221
+ 22.5 hr	12.8	36	6.03	14,900	73	525	11,730	208	56	2,045	101
+ 23.5 hr	12.3	37	5.84	16,200	0	719	12,792	336	184	1,880	125
+ 24.5 hr	17.7	35	5.85	13,900	21	155	11,529	86	98	1,496	108
+ 26.5 hr	11.7	37	5.98	11,200	0	229	8,916	197	40	1,610	119
+ 28.5 hr	11.2	35	5.73	11,900	31	399	8,991	370	0	1,930	125
+ 30.5 hr	11.3	35	5.67	12,500	0	310	10,044	282	31	1,677	90
+ 32.5 hr	11.8	36	5.96	11,700	27	201	9,478	259	69	1,547	95
+ 34.5 hr	10.6	31	5.65	11,500	0	37	9,146	282	89	1,531	284
+ 36.5 hr	11.1	32	5.71	12,500	0	214	9,788	360	0	1,545	284
+ 40.5 hr	11.3	33	5.92	10,500	0	33	8,270	175	69	1,440	276
+ 44.5 hr	11.7	35	5.96	10,900	0	0	9,105	179	32	1,174	243
+ 48.5 hr	12.4	36	6.41	11,100	0	83	9,382	305	76	999	118
+ 3 day	14.2	41	7.29	15,000	0		12,072	461	0	1,891	461

Table 4. ABSOLUTE HEMATOLOGICAL VALUES

Burro: Composite			Group: Control		Dose: 600 r							
R HOUR	HB	HEM	RBC	WBC	EOS	IMM STAB	SEG	TRANS	LL	M&S	PCP PCL	
<u>Pre-sham irradiation</u>												
-6 day	11.2	34	5.59	10,918	890	128	6,027	324	216	3,718	168	
-5 day	11.0	34	5.90	10,291	692	52	4,835	143	48	3,486	308	
-4 day	11.0	34	5.91	10,381	966	0	4,758	76	276	4,255	324	
-3 day	11.3	35	5.99	10,432	805	37	4,714	201	147	3,883	246	
-50 hr	11.6	35	6.04	10,246	791	65	4,546	287	162	3,605	336	
-48 hr	11.8	36	5.99	10,866	887	22	4,028	284	188	4,936	383	
-47.5 hr	11.6	35	6.05	10,135	713	77	4,074	241	223	4,239	247	
-46.5 hr	12.7	36	6.18	10,905	744	19	4,998	231	180	4,639	226	
-44.5 hr	11.9	32	6.08	11,630	944	25	4,445	365	72	4,726	241	
-43.5 hr	11.8	33	6.15	11,772	1,062	0	5,995	173	121	4,437	405	
-42.5 hr	12.0	34	5.88	12,873	939	47	6,283	272	216	4,513	268	
-41.5 hr	12.4	35	6.03	12,925	1,205	33	6,992	351	196	4,455	252	
<u>Sham irradiation</u>												
-26 hr	12.0	36	6.20	12,030	7,137	51	5,354	296	79	4,659	222	
-24 hr	12.8	38	6.59	12,043	822	59	4,855	298	139	4,630	308	
-23.5 hr	13.1	39	6.73	12,822	681	49	7,493	471	145	3,548	149	
-22.5 hr	12.6	38	6.50	13,342	681	17	7,827	232	151	4,629	286	
-20.5 hr	11.0	34	5.85	13,588	595	42	8,390	301	224	3,478	197	
-19.5 hr	11.2	34	6.07	13,343	508	73	8,631	406	97	3,251	256	
-18.5 hr	10.4	33	5.60	13,420	666	32	8,368	290	89	3,393	393	
-17.5 hr	10.2	31	5.93	12,604	337	100	7,913	370	37	3,449	362	
<u>Irradiation</u>												
-2 hr	10.9	33	5.95	11,953	1,000	32	6,417	406	89	3,410	183	
0 hr	12.5	36	6.46	13,372	789	25	6,317	218	184	5,206	360	

Table 4 (cont'd)

R HOUR	HB	HEM	RBC	WBC	EOS	IMM STAB	SEG	TRANS	LL	M&S	PCP PCL
+ .5 hr	13.6	40	6.79	14,512	781	96	7,915	349	205	4,260	310
+1.5 hr	12.6	37	6.45	14,419	861	154	8,537	497	75	5,733	321
+3.5 hr	10.8	33	5.54	13,127	504	70	7,519	131	211	2,891	287
+4.5 hr	10.9	32	5.51	13,547	617	64	7,847	248	196	3,576	73
+5.5 hr	10.5	32	5.76	13,280	605	49	8,652	221	62	4,093	287
+6.5 hr	10.8	32	5.63	13,173	499	153	7,419	251	131	4,269	383
+7.5 hr	11.4	35	5.73	12,673	428	104	6,881	244	100	4,040	353
+8.5 hr	11.3	35	5.84	12,378	752	53	6,879	241	218	3,929	225
+9.5 hr	11.2	33	5.70	12,433	507	0	7,245	180	116	3,946	239
+10.5 hr	11.1	33	5.59	12,167	802	68	8,765	394	140	3,751	301
+11.5 hr	11.2	34	5.97	13,080	607	98	5,938	191	189	4,190	239
+12.5 hr	10.8	33	5.63	11,628	671	13	5,766	216	81	3,929	277
+13.5 hr	11.6	35	5.86	11,560	624	57	6,141	267	257	3,784	426
+14.5 hr	11.6	35	5.86	11,945	685	18	6,135	364	204	3,951	236
+15.5 hr	12.0	37	6.16	12,127	618	55	5,760	342	247	4,099	261
+16.5 hr	11.4	34	5.81	11,575	749	12	6,013	298	314	3,569	207
+17.5 hr	11.5	34	5.79	10,929	887	0	5,858	332	179	3,471	207
+18.5 hr	11.1	33	5.63	11,027	808	47	5,664	200	299	3,408	205
+19.5 hr	11.1	34	5.74	10,694	738	39	5,327	269	60	3,589	241
+20.5 hr	11.2	34	5.97	10,888	808	17	5,548	302	94	3,704	245
+21.5 hr	11.0	33	5.96	11,130	843	97	5,606	295	142	3,800	198
+22.5 hr	12.2	35	6.30	11,952	685	41	6,751	228	225	3,703	168
+23.5 hr	11.0	33	6.09	9,907	686	38	5,134	388	91	3,742	202
+24.5 hr	10.6	33	5.79	10,326	626	0	5,271	267	0	3,264	194
+26.5 hr	10.9	35	5.68	9,906	739	47	5,379	680	286	2,956	356
+28.5 hr	10.8	34	5.83	10,282	731	28	5,481	326	117	3,317	227
+30.5 hr	10.8	34	5.75	10,352	838	0	5,328	468	42	3,311	246
+32.5 hr	10.2	33	5.68	10,358	531	0	5,635	269	154	3,247	261
+34.5 hr	10.0	30	5.56	10,095	546	0	6,071	479	147	3,637	309
+36.5 hr	11.4	34	6.02	9,159	581	0	4,346	269	35	2,934	166
+40.5 hr	11.0	32	5.91	8,549	588	29	4,203	213	95	2,738	286
+44.5 hr	11.0	33	5.83	8,995	707	0	4,992	434	54	2,734	272
+48.5 hr	11.2	35	5.93	9,615	551	0	4,783	225	85	3,686	255
+3 day	12.5	36	6.61	9,824	522	31	4,663	368	166	3,984	255

Table 5. ABSOLUTE HEMATOLOGICAL VALUES

Burro: Composite			Group: Control		Dose: 200 r							
R HOUR	HB	HEM	RBC	WBC	EOS	IMM STAB	SEG	TRANS	LL	M&S	PCP PCL	
<u>Pre-sham irradiation</u>												
-6 day	9.9	30	5.17	10,500	1,263	0	5,526	0	101	3,235	268	
-5 day	9.7	30	5.31	12,625	1,624	45	6,332	45	194	3,883	276	
-4 day	9.3	31	5.44	10,625	1,193	28	5,266	104	27	3,590	231	
-3 day	10.5	29	5.18	11,800	1,200	0	5,420	121	204	3,354	249	
-50 hr	10.8	30	5.53	11,925	1,548	117	5,218	226	238	3,966	453	
-48 hr	10.8	31	5.49	11,475	1,801	22	4,740	365	200	3,994	365	
-47.5 hr	9.5	29	4.93	10,400	1,209	85	4,658	247	188	3,459	262	
-46.5 hr	10.3	30	5.16	10,055	1,196	0	5,495	125	196	2,716	156	
-44.5 hr	10.3	30	4.70	11,550	1,082	21	6,064	93	285	3,410	331	
-43.5 hr	10.3	30	5.00	11,825	1,191	18	5,907	184	105	3,577	484	
-42.5 hr	10.4	30	5.12	11,800	1,126	18	5,975	99	246	3,889	122	
-41.5 hr	10.0	31	5.08	11,225	1,368	0	5,937	144	91	3,230	188	
<u>Sham irradiation</u>												
-26 hr	10.3	30	5.24	11,400	1,582	23	5,154	121	144	3,869	159	
-24 hr	10.9	31	5.49	12,400	1,394	55	5,585	217	189	4,094	481	
-23.5 hr	11.1	31	5.36	14,325	1,265	292	7,884	527	182	3,736	274	
-22.5 hr	11.0	31	5.39	14,100	1,247	206	8,640	176	75	3,238	308	
-20.5 hr	9.9	29	5.07	14,575	840	74	10,000	152	72	2,813	189	
-19.5 hr	9.8	29	5.08	14,050	364	41	9,473	162	161	3,441	208	
-18.5 hr	9.2	28	4.81	13,450	440	35	9,081	110	75	3,096	375	
-17.5 hr	9.5	28	4.78	12,225	553	0	8,166	120	25	2,695	480	
<u>Irradiation</u>												
-2 hr	10.2	30	5.33	12,575	1,190	55	6,739	222	98	3,648	420	
0 hr	11.4	34	5.41	11,075	1,533	98	5,460	244	215	2,834	506	
+ .5 hr	11.7	34	5.80	13,550	1,061	158	7,934	186	61	3,251	534	
+1.5 hr	11.7	33	5.34	13,850	1,040	182	8,072	272	202	3,464	338	
+3.5 hr	9.5	29	4.93	11,250	584	41	7,264	306	116	2,540	85	
+4.5 hr	9.9	29	5.12	10,800	692	180	6,837	143	52	2,261	365	

Table 5 (cont'd)

R HOUR	HB	HEM	RBC	WBC	EOS	IMM STAB	SEG	TRANS	LL	M&S	PCP PCL
+ 5.5 hr	9.9	28	4.85	11,650	768	78	6,992	233	146	3,013	289
+ 6.5 hr	9.4	28	5.05	11,500	446	94	6,779	204	33	3,683	145
+ 7.5 hr	9.7	28	5.03	11,025	648	80	6,370	226	87	3,260	245
+ 8.5 hr	9.9	29	5.29	11,825	1,238	53	6,278	167	52	2,572	57
+ 9.5 hr	10.3	30	5.92	10,625	774	27	6,196	80	80	2,880	289
+ 10.5 hr	9.8	29	5.46	11,800	1,206	111	6,334	115	109	3,320	352
+ 11.5 hr	9.5	29	4.85	11,425	978	145	6,319	228	82	3,270	286
+ 12.5 hr	9.8	38	4.87	10,075	1,005	29	5,240	217	106	3,013	169
+ 13.5 hr	9.3	28	4.93	11,050	1,004	55	5,678	221	280	3,343	162
+ 14.5 hr	9.5	29	4.85	10,025	1,195	101	5,494	101	25	2,632	270
+ 15.5 hr	9.1	28	4.77	9,600	1,175	51	4,959	161	146	2,681	264
+ 16.5 hr	9.4	28	4.88	9,975	1,306	26	5,305	99	125	2,885	150
+ 17.5 hr	9.3	28	4.82	10,225	1,426	77	5,153	124	102	3,056	161
+ 18.5 hr	9.7	29	4.97	10,775	1,199	132	5,384	104	107	3,435	278
+ 19.5 hr	9.4	28	4.99	11,075	1,175	188	5,619	198	255	3,225	141
+ 20.5 hr	10.5	31	5.35	11,350	1,204	179	5,096	260	218	3,855	326
+ 21.5 hr	10.3	31	5.10	11,225	1,097	0	5,663	108	201	3,532	220
+ 22.5 hr	9.6	29	5.05	9,825	1,286	121	5,187	163	123	2,584	169
+ 23.5 hr	9.6	29	4.94	10,650	1,603	125	5,447	141	142	2,823	236
+ 24.5 hr	9.4	28	4.85	10,425	1,090	67	4,965	87	237	3,565	280
+ 26.5 hr	9.2	28	5.07	9,675	1,072	59	4,320	228	0	3,694	214
+ 28.5 hr	9.5	29	5.07	10,475	1,488	23	4,370	126	282	3,844	186
+ 30.5 hr	9.9	30	5.22	10,150	1,249	128	4,912	256	42	3,725	190
+ 32.5 hr	9.3	30	5.02	9,750	1,499	97	3,769	72	0	3,960	276
+ 34.5 hr	9.4	30	4.99	10,975	1,326	41	5,185	64	169	3,732	272
+ 36.5 hr	10.1	32	5.34	10,950	1,420	0	4,457	230	65	4,261	270
+ 40.5 hr	10.8	33	5.77	11,100	1,661	77	4,258	151	102	4,339	271
+ 44.5 hr	9.9	31	5.35	11,275	1,165	37	4,831	141	122	4,505	119
+ 48.5 hr	10.1	31	5.29	10,825	1,055	0	5,538	356	22	3,288	246
+ 3 day	10.4	30	5.25	11,675	1,199	50	5,726	181	27	3,792	390
+ 4 day	10.3	30	5.37	11,250	1,405	53	5,334	205	128	3,612	256
+ 5 day	10.5	31	5.33	12,125	1,777	22	5,358	147	28	4,187	285
+ 6 day	10.3	31	5.26	11,200	1,130	31	5,606	187	118	3,390	371
+ 1 week	10.5	32	5.33	12,350	1,383	56	5,725	219	190	3,988	317
+ 2 week	10.5	32	5.49	9,900	1,050	91	4,505	177	0	3,593	387

Table 5 (cont'd)

R HOUR	HB	HEM	RBC	WBC	EOS	IMM STAB	SEG	TRANS	LL	M&S	PCP PCL
+ 3 week	10.8	32	5.67	11,625	1,169	95	5,625	223	386	3,718	223
+ 4 week	12.3	34	5.99	13,675	1,565	92	6,558	247	153	4,223	426
+ 5 week	10.6	32	5.44	11,850	1,773	247	4,743	240	223	4,261	217
+ 6 week	10.6	32	5.42	13,350	1,685	213	5,326	142	272	4,824	449

Table 6. ABSOLUTE HEMATOLOGICAL VALUES

Burro: Composite			Group: Irradiated		Dose: 200 r							
R HOUR	HB	HEM	RBC	WBC	EOS	IMM STAB	SEG	TRANS	LL	M&S	PCP PCL	
<u>Pre-sham irradiation</u>												
-6 day	9.8	32	5.30	8,898	570	75	4,800	115	125	2,246	116	
-5 day	10.4	32	5.58	9,740	550	22	4,657	173	171	3,061	300	
-4 day	10.5	34	5.62	10,566	747	53	5,318	460	204	4,427	231	
-3 day	10.2	31	5.52	10,959	1,307	81	5,418	294	230	3,269	150	
-50 hr	10.7	32	5.77	10,625	587	29	5,302	277	202	3,637	171	
-48 hr	10.5	30	5.61	10,424	1,236	65	5,880	45	200	2,871	130	
-47.5 hr	10.6	31	5.78	10,299	623	0	5,062	116	215	3,940	247	
-46.5 hr	10.3	31	5.73	10,108	732	95	5,043	208	200	2,986	193	
-44.5 hr	10.5	31	5.71	10,449	641	22	5,665	236	145	3,089	194	
-43.5 hr	10.5	31	5.73	11,424	617	37	6,449	262	94	3,724	204	
-42.5 hr	10.3	31	5.73	12,399	639	81	7,438	202	99	3,843	419	
-41.5 hr	10.1	30	5.39	12,483	783	69	7,163	74	124	4,153	390	
<u>Sham irradiation</u>												
-26 hr	10.1	28	5.40	12,244	540	74	6,777	159	139	3,530	159	
-24 hr	11.4	32	5.67	11,599	848	94	6,761	139	118	3,672	192	
-23.5 hr	11.5	33	5.92	11,996	1,215	33	7,884	236	84	3,625	144	
-22.5 hr	11.1	33	5.82	12,658	719	95	7,629	350	70	3,321	390	
-20.5 hr	10.7	32	5.79	13,466	485	0	8,538	346	118	3,154	385	
-19.5 hr	9.8	29	5.18	13,574	435	0	9,558	252	149	2,917	177	
-18.5 hr	9.5	28	5.03	12,808	497	60	8,642	270	186	3,010	252	
-17.5 hr	9.8	29	5.24	11,724	392	54	8,144	289	196	2,456	195	
<u>Irradiation</u>												
-2 hr	10.2	30	5.36	10,649	829	84	5,375	206	121	3,439	78	
0 hr	11.1	34	6.01	10,441	643	82	5,412	228	57	3,198	136	
+ .5 hr	11.1	33	5.92	10,966	693	58	5,924	452	73	3,617	217	
+1.5 hr	11.2	34	6.02	11,358	738	74	6,935	293	116	3,236	165	
-3.5 hr	10.2	31	5.35	11,241	484	63	7,280	381	125	3,379	166	

Table 6 (cont'd)

R HOUR	HB	HEM	RBC	WBC	EOS	IMM STAB	SEG	TRANS	LL	M&S	PCP PCL
+4.5 hr	9.8	29	5.20	10,891	509	173	7,022	255	87	2,314	186
+5.5 hr	9.5	28	5.11	10,966	446	184	7,069	225	61	2,407	263
+6.5 hr	10.1	29	5.05	10,974	447	0	7,737	51	58	2,794	147
+7.5 hr	9.5	29	5.45	10,916	549	28	6,980	194	42	2,688	169
+8.5 hr	9.8	29	5.25	11,116	403	107	6,805	239	164	2,415	253
+9.5 hr	9.7	29	5.30	10,916	487	19	7,103	167	178	3,368	167
+10.5 hr	9.8	29	5.14	13,166	678	88	6,324	267	46	2,464	267
+11.5 hr	9.7	29	5.30	10,016	522	147	5,929	183	200	2,613	183
+12.5 hr	9.8	29	5.26	9,658	816	76	5,780	170	23	2,606	170
+13.5 hr	9.9	30	5.23	9,558	477	49	5,505	101	124	2,476	101
+14.5 hr	9.7	30	5.35	9,733	571	44	5,443	224	163	2,697	224
+15.5 hr	10.1	30	5.40	9,924	638	24	5,881	135	171	3,207	135
+16.5 hr	10.8	32	5.90	9,991	762	51	6,263	151	103	2,104	151
+17.5 hr	10.3	32	5.52	9,566	565	28	5,632	199	69	2,989	199
+18.5 hr	9.7	28	5.17	9,474	489	24	5,289	160	156	2,646	160
+19.5 hr	9.8	30	5.38	9,108	853	77	5,248	158	86	2,687	160
+20.5 hr	10.7	32	5.65	9,266	652	62	4,908	105	65	2,630	105
+21.5 hr	9.8	29	5.53	9,699	668	68	4,899	103	0	3,068	103
+22.5 hr	10.3	30	5.58	9,924	845	84	6,468	197	85	2,949	197
+23.5 hr	10.0	30	5.35	9,849	799	46	5,593	143	0	2,614	143
+24.5 hr	9.8	29	5.06	8,824	793	29	4,853	343	71	2,654	114
+26.5 hr	9.9	30	5.27	8,791	656	14	3,814	29	50	3,090	29
+28.5 hr	10.1	30	5.37	9,000	764	52	4,911	232	50	2,977	232
+30.5 hr	9.8	30	5.25	9,658	913	82	5,097	106	100	2,974	106
+32.5 hr	9.8	30	5.31	9,741	715	181	4,906	505	25	2,873	505
+34.5 hr	9.6	30	5.22	9,674	738	25	5,066	187	63	3,055	187
+36.5 hr	9.8	31	5.48	9,683	702	115	4,744	295	101	2,960	295
+40.5 hr	10.0	30	5.57	9,682	804	29	4,771	142	121	3,820	97
+44.5 hr	10.2	31	5.53	9,792	923	49	4,923	589	74	2,965	88
+48.5 hr	10.2	32	5.50	9,499	805	106	5,415	315	22	2,878	131
+3 day	9.8	30	5.49	9,580	422	95	5,169	363	89	2,794	71
+4 day	10.8	32	5.75	9,999	801	23	4,846	356	165	3,408	315
+5 day	11.3	34	5.81	10,591	957	80	5,719	414	28	3,331	136
+6 day	11.7	33	5.72	10,999	1,081	0	5,543	284	148	3,336	266

Table 6 (cont'd)

R HOUR	HB	HEM	RBC	WBC	EOS	IMM STAB	SEG	TRANS	LL	M&S	PCP PCL
+1 week	10.4	30	5.60	10,591	836	137	5,884	261	178	3,769	218
+2 week	10.9	32	5.93	11,016	644	0	4,132	134	49	4,245	193
+3 week	11.2	32	5.95	10,824	863	153	6,118	229	151	3,987	309
+4 week	11.0	31	5.75	11,599	842	0	5,113	140	123	4,263	179
+5 week	10.6	32	5.73	11,583	1,047	108	5,445	107	131	3,791	229
+6 week	9.3	28	5.00	11,975	984	29	6,025	34	0	4,469	279

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